

Cozmo Forklifts Things

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Goal

Our goal for this project was to have Cozmo pick up pallets using Hexnub's lifting kit.



Detection Strategies

We wanted to be able to lift pallets with objects on top of the pallet which would require us to use only the side of the pallet to identify and dock with the pallets. We also wanted to be able to detect the pallets on any reasonably colored table surface.

Convolutional Neural Network

We first considered a convolutional neural network for recognizing the pallets. Based on our work on lab 10, we used 15,000 unique background images and still failed to consistently classify whether or not a cube was in Cozmo's image or not. Considering the fewer features on the Hexnub pallets and the need for information about the orientation of the pallet, we decided that a convolutional neural network would not be appropriate for our project which would be due in several weeks.

Retro-Reflective Tape

We considered using retro-reflective tape for identifying and localizing the pallets. Our hope was that the infrared LED on Cozmo would illuminate the retroreflective tape sufficiently for it to

appear on Cozmo's camera. After we put the tape on the pallet's corners and used the camera, we did not see noticeable contrast between the tape and the pallet even in a dark environment. We tried a simple camera flash and saw the significant contrast we would expect. We suspect that Cozmo's infrared LED is not necessarily bright enough. We also believe that the LED being pointed forward rather than in the same direction as the camera hindered us.

Coloured Tape

After retroreflective tape failed to provide enough contrast, we tried bright yellow tape and configured Cozmo to use the colour image. We were able to isolate the yellow tape using thresholding and segmentation, but we had difficulty using the data to localize the pallet. We tried using the visible area of the tape to determine the distance to the pallet, but found that the visible area changed significantly with no change in the environment. We found that, even at short distances, the transient noise from the image compression was altering the size of our segmented area by several centimetres which would not be accurate enough for us to dock with the pallet.

Aruco Markers

The solution we found worked best was putting an Aruco markers on the center peg of each side of the pallet. The Aruco markers had been shown to work well on previous labs with the world map doorways provided by Dr. Touretzky.

A challenge with Aruco markers was that the markers were significantly smaller than those used for the doorways. The markers needed to be as large as possible for visibility, but also had to retain a white border around the marker to enable detection. They also needed to be narrow enough that the marker would not block the forks from going into the pallet. The spaces between the works is only 12mm. After significant trial and error, we settled upon 9mm markers with approximately 1mm of white border on each side.

Luckily, OpenCV's infrastructure for Aruco markers made it easier for us to localize the pallet. Once the markers were visible, we did not have to write too much code to calculate the location and orientation of the pallet.

Pickup Strategies

In this section we will focus on the more interesting iterations we went through in portions of our strategy for picking up pallets.

Initial Pallet Approach

While we can detect the presence of a pallet from some distance away, the accuracy of our measurement is obviously lower at greater distances. At first, we tried to square up to the pallet based on this initial measurement, but this proved ineffective. We found much greater success when we decided have our first step be to turn towards and drive to a set desired distance away

from the pallet, regardless of its apparent orientation. This allowed the camera to get a much better look at the pallet before moving on to the next major phase.

Squaring Up

Because the pallet may be an arbitrary angle when we approach it, we have a phase where we “square up” to the pallet, trying to be a set distance away and facing the pallet along a vector orthogonal to the select pallet face. We initially tried the PilotToPose command. Unfortunately, we found its accuracy insufficient for our purposes. Most frustrating was its tendency to make wild, harsh turns and generally get off course. Next, we tried using our own three step move, where we would turn in the direction of the desired position, drive forward, and then turn to face the pallet’s last known position. This worked much better. However, we also experimented with the Cozmo SDK-based GoToPose node. This had significantly greater accuracy, and seemed well tuned to handle both short, precise moves as well as longer ones. We ultimately settled on GoToPose in our demo and final submission.

Lift Height

We wanted to be able to pick up pallets whether they were on the ground or on top of some object. The lift height was worrying because we believe there is not a linear relationship between the selected lift height (in the range from 0 to 1) and the actual height of the lift. However, we were successfully able to conduct some experimental measurements and made an linear approximation of the relationship between the desired lift height and the observed height of pallet off of the ground. This had great success and we are able to get the right lift height on the variety of surfaces we tested. One important note is that Cozmo’s lift is not very good at making small relative movements. Because of this, if our desired lift height is below 0.5, we first move the lift to 0.75 before moving it to the desired height. Otherwise, we move it to 0.25 before the desired height. This results in the final movement always being no less than 0.25, which is sufficiently large for Cozmo to perform accurately.

Results

Using the Aruco markers and GoToPose pickup strategy, we were able to consistently pick up pallets that were on the ground and up to approximately 3.5cm above the ground. We ran our tests with a small pack of staples taped to the pallet. The weight of the staples helped the pallet stay in place when the forklifts were skewering it and the staples’ low centre of gravity prevented it from tipping or falling off when it was being lifted and carried.

We also have support for multiple distinct pallets. Cozmo can be made to focus on a single pallet for pickup. Arbitrary pallets can be configured, so long as the user specifies which Aruco markers are on the pallet at the beginning of the state machine program.

We found that there are still some cases where Cozmo will struggle to pick up the pallet. When the object on the pallet is too heavy, Cozmo will tip forward trying to lift the pallet, dropping the

pallet and the object. This is a limitation in Cozmo's hardware and not something we could remedy within our code.

When the object on the pallet has a high center of gravity, the object will sometimes fall off the pallet while Cozmo is lifting it or carrying it to its destination. Slowing down Cozmo's driving occasionally fixed this issue, but for our tests, we taped the object to the pallet to prevent it from tipping or sliding off the pallet.

In Cozmo's final adjustments for "Squaring Up" with the pallet, Cozmo would occasionally over or under-turn on its small turns. We noticed that in the Turn node, there was a minimum angle of 2 degrees. We tried using the SmallTurn node from cozmo-tools instead and did not have noticeable improvements. Even on angles as large as 2 or 3 degrees, Cozmo would not be able to accurately turn towards the Aruco marker. The small error in angle usually was not enough to prevent Cozmo from picking up the pallet, but for the cases where it did fail, we added functionality for Cozmo to try again. Since this failure rarely prevented Cozmo from picking up the pallet, it seldom needed more than 2 tries to pick up the pallet.

Future Work

A feature that could be added to this project could be a sequence of movements that could flip over a pallet. Using manual control, we were able to flip over a pallet by skewering it with only one fork, raising the lift, and then placing it down while turning the robot to one side. A potential future project could be to create a state machine node that would perform this sequence of moves consistently. For our tests, we had the pallet resting on the surface with the "H" since it had more friction than the side of the pallet with the Lego pegs. It may be beneficial to flip over pallets that are resting on the wrong surface.

Pallet Images

Pallet With Aruco Markers



Pallet With Colored Tape

